

I CLAIM:

- 1 1. An internal combustion engine arrangement comprising:
2 a spark-ignited internal combustion engine;
3 an exhaust line receiving exhaust gas from the internal combustion engine;
4 an oxide gas absorber in the exhaust line including a support member; and an
5 absorption layer on a surface of the support member having an enlarged surface area
6 accessible to exhaust gas flowing through the exhaust line for reversible absorption at
7 least one nitrogen oxide (NO_x) and/or at least one oxide of sulfur (SO_x); and,
8 a control unit for controlling the temperature of the absorption layer by adjusting
9 parameters of the exhaust gas so that the absorption layer can be heated to a temperature
10 at which the layer is regenerated by desorbing absorbed NO_x or SO_x .
- 1 2. An internal combustion engine arrangement according to claim 1 wherein
2 the support member is a metal support member.
- 1 3. An internal combustion engine arrangement according to claim 2 wherein
2 the metal support member is a metal foil.
- 1 4. An internal combustion engine arrangement according to claim 2 wherein
2 the metal support member is heatable by application of an electric current.
- 1 5. An internal combustion engine arrangement according to claim 2 wherein
2 the metal support member has a wall thickness ≤ 0.1 mm.

1 6. An internal combustion engine arrangement according to claim 5 wherein
2 the metal support member has a wall thickness ≤ 0.06 mm.

1 7. An internal combustion engine arrangement according to claim 1 wherein
2 the support member contains a plurality of parallel passages having a closed cross-section
3 through which exhaust gas can be passed and the absorption layer is on the inside surface
4 of the passages.

1 8. An internal combustion engine arrangement according to claim 7 wherein
2 at least some of the passages have a structure causing turbulent gas flow at least over a
3 portion of the passage.

1 9. An internal combustion engine arrangement according to claim 8 wherein
2 the structure causing the turbulent gas flow is at least one of: (a) a variation in cross-
3 section; (b) a corrugation; and (c) a twisting or curvature of the passages.

1 10. An internal combustion engine arrangement according to claim 7 wherein
2 the oxide gas absorber is subdivided into a plurality of segments.

1 11. An internal combustion engine arrangement according to claim 10 wherein
2 the plurality of segments have at least one of: (a) different lengths; (b) different passage
3 cross-sections; (c) different numbers of passages; and (d) spacing between segments of at
4 least 50 cm.

1 12. An internal combustion engine arrangement according to claim 1 wherein
2 the enlarged surface area provides an area of at least 20 m² accessible to the exhaust gas
3 per gram of the absorption layer.

1 13. An internal combustion engine arrangement according to claim 12 wherein
2 the enlarged surface area provides an area of at least 40 m² accessible to the exhaust gas
3 per gram of the absorption layer.

1 14. An internal combustion engine arrangement according to claim 13 wherein
2 the enlarged surface area provides an area of at least 100 m² accessible to the exhaust gas
3 per gram of the absorption layer.

1 15. An internal combustion engine arrangement according to claim 1 wherein
2 the absorption layer contains an aluminum oxide.

1 16. An internal combustion engine arrangement according to claim 15 wherein
2 the absorption layer contains gamma aluminum oxide.

1 17. An internal combustion engine arrangement to claim 1 wherein the
2 absorption layer contains an element selected from the group consisting of alkali metals,
3 alkaline-earth metals, rare earths, lanthanum, titanium, copper and manganese..

1 18. An internal combustion engine arrangement according to claim 1 wherein
2 the absorption layer contains at least one of the elements barium, sodium and potassium.

1 19. An internal combustion engine arrangement according to claim 1 wherein
2 the absorption layer absorbs NO_x and/or SO_x from an exhaust gas with an excess of
3 oxygen during lean operation of the internal combustion engine.

1 20. An internal combustion engine arrangement according to claim 1 wherein
2 the absorption layer releases NO_x and/or SO_x in a reducing atmosphere and/or at low
3 oxygen concentration in the exhaust gas.

1 21. An internal combustion engine arrangement according to either of claim
2 19 or claim 20 including an oxygen concentration determining means for determining a
3 value representing the oxygen concentration in the exhaust gas and supplying a signal
4 representing the oxygen concentration as an input signal to the control unit, and wherein
5 the control unit uses the oxygen concentration signal to control charging or discharging of
6 the absorber.

1 22. An internal combustion engine arrangement according to claim 1 wherein
2 the absorption layer desorbs NO_x and SO_x at an elevated temperature.

1 23. An internal combustion engine arrangement according to claim 22
2 including a temperature determining means for determining a value representing the
3 temperature of at least one of: (a) the exhaust gas; (b) the absorption layer; and
4 (c) the support member; and supplying a signal corresponding to that value as an input
5 signal to the control unit for control of charging or discharging of the absorber.

1 24. An internal combustion engine arrangement according to claim 23
2 wherein the control unit receives signals representing both the oxygen concentration in
3 the exhaust gas and the temperature of the exhaust gas as input signals.

1 25. An internal combustion engine arrangement according to claim 1 wherein
2 the support member is a ceramic member and the absorption layer has a thickness of at
3 least 50 microns.

1 26. An internal combustion engine arrangement according to claim 1 wherein
2 the support member is a metal member and the absorption layer has a thickness of at least
3 25 microns.

4 27. An internal combustion engine arrangement according to claim 1 wherein
5 the absorption layer is applied as a wash coat.

1 28. An internal combustion engine arrangement according to claim 1 wherein
2 the absorption layer contains at least one precious metal.

1 29. An internal combustion engine arrangement according to claim 28 wherein
2 the absorption containing the precious metal constitutes an oxidation catalyst or a three-
3 way catalyst.

1 30. An internal combustion engine arrangement according to claim 1 wherein
2 the absorption layer accessible to the exhaust gas has a pore volume of at least 0.2 cm³/g.

1 31. An internal combustion engine arrangement according to claim 1
2 including an oxidation catalyst separate from the oxide gas absorber.

1 32. An internal combustion engine arrangement according to claim 31 wherein
2 the oxidation catalyst is a three-way catalyst.

1 33. A method for removing at least one nitrogen oxide (NO_x) from the exhaust
2 gas of an internal combustion engine, comprising the steps of:

3 (a) operating an internal combustion engine to produce an exhaust gas flow
4 containing oxygen;

5 (b) passing exhaust gas containing oxygen over an absorber containing an
6 absorbing layer on a surface of a support member;

7 (c) storing the NO_x in the absorbing layer;

8 (d) heating the absorbing layer to a predetermined temperature during the
9 operation of the engine;

10 (e) producing an exhaust gas which is poor in oxygen or an exhaust gas having a
11 stoichiometric excess of a reducing agent;

12 (f) desorbing the NO_x from the absorbing layer and reducing the NO_x in the
13 exhaust gas which is poor in oxygen has a stoichiometric excess of reducing agent while
14 the absorbing layer is at a temperature equal to or above the predetermined temperature;

15 (g) again producing an exhaust gas containing oxygen;

16 (h) terminating heating of the absorbing layer to the predetermined temperature;

17 and

18 (j) repeating steps (c) through (h).



1 34. A method according to claim 33 wherein the step of heating the absorbing
2 layer is carried out by at least one of: (a) injecting fuel into the exhaust gas and catalytic
3 combustion thereof, (b) varying the operating conditions of the internal combustion
4 engine, (c) electrical heating of the absorbing layer and (d) using a burner to heat the
5 exhaust gas.

1 35. A method according to claim 33 wherein, before the step of heating the
2 absorbing layer at least to a predetermined temperature during operation of the internal
3 combustion engine, a step of determining whether a temperature value representing the
4 temperature of the absorbing layer is at or above the predetermined temperature is carried
5 out and, if it is determined that the temperature value representing the temperature of the
6 absorbing layer is at or above the predetermined temperature, steps (d) and (b) are
7 omitted.

1 36. A method according to any one of claims 33-35 wherein the support
2 member is a metal support member.

1 37. A method according to any one of claims 33-35 wherein at least one oxide
2 of sulfur (SO_x) is also stored and desorbed by the absorbent layer.

1 38. A method according to any one of claims 33-35 wherein the desorption
2 from the absorber layer is carried out at periodic intervals.

1 39. A method according to any one of claims 33-35 wherein the desorption
2 from the absorbent layer is carried out depending on the amount of gas stored in the
3 absorbent layer.



1 40. A method according to any one of claims 33- 35 wherein the absorbent
2 layer contains gamma-aluminum oxide and at least one element in the group consisting of
3 alkali metals, alkaline-earth metals, rare earths and lanthanum.

1 41. A method according to any one of claims 33-35 wherein the exhaust gas is
2 passed over the absorbent layer with turbulence.

1 42. A method according to any one of claims 33-35 wherein the support
2 member has a plurality of parallel passages..

1 43. A method according to claim 42 wherein the exhaust gas is passed over a
2 plurality of support members containing the gas absorbing layer and having at least one
3 of: (a) different numbers of passages; (b) passages of different flow diameters; and (c)
4 spacings between the support members of at least 50 cm.

1 44. A method according to claim 42 wherein the support member has a
2 plurality of twisted or curved passages.